

CHAPTER 3

PUMPING EQUIPMENT

3-1. Pumps.

a. General. The location of the pump station and intake structure, and the anticipated heads and capacities are the major factors in the selection of pumps. The function of a pump station in the overall distribution system operation can also affect the determination of capacities. Basic pump hydraulic terms and formulas, pump fundamentals and applications, and instructions for installation, operation and maintenance are given in the Hydraulic Institute Engineering Data Book and Hydraulic Institute Standards. It is recommended that these books be part of the permanent library of the fluid system designer.

b. Pump types. There are generally two types of pumps used for potable water pumping applications—the vertical turbine pump, line shaft and submersible types, and the centrifugal horizontal or vertical split case pump designed for water-works service. If the pump station and intake structure are to be located within a surface or underground reservoir, vertical turbine pumps with the column extending down into the reservoir or its suction well will be a logical choice. If the pump station is located at an above ground storage facility, split case centrifugal pumps will be the preferred selection. These pumps are normally horizontal but vertical split case pumps are common where there is limited space. Flexible couplings will connect pump and driver shafts. Split case pump design is used for ease of maintenance of the rotating elements, which can be removed without disconnecting the suction or discharge piping.

For standard waterworks design for potable systems, pump casing will be cast iron and impellers will be bronze. Base for pump and driver will be cast iron or fabricated steel. Pump impeller and casing may have wearing rings depending upon manufacturers' recommendations and consideration of the cost of replacing the rings. Pumps will have mechanical seals or packing seals, ball or roller bearings, and lubrication system. Pumps which may operate under extreme conditions such as at the ends of pump curves or under frequent on-off operation will have packing seals in lieu of mechanical seals. Mechanical seals will be considered for pumps likely to stand idle for long periods of time. Where scale or abrasive water conditions exist, pump linings and other material options for impeller, shaft, wear rings, and seals are available. A water analysis at the point of service must be secured and analyzed before non-standard materials

are selected. Lubrication for horizontal pumps will be oil bath or grease. Vertical dry pit pumps will be grease lubricated. Vertical wet pit pumps will have oil or water lubrication.

c. Pump applications.

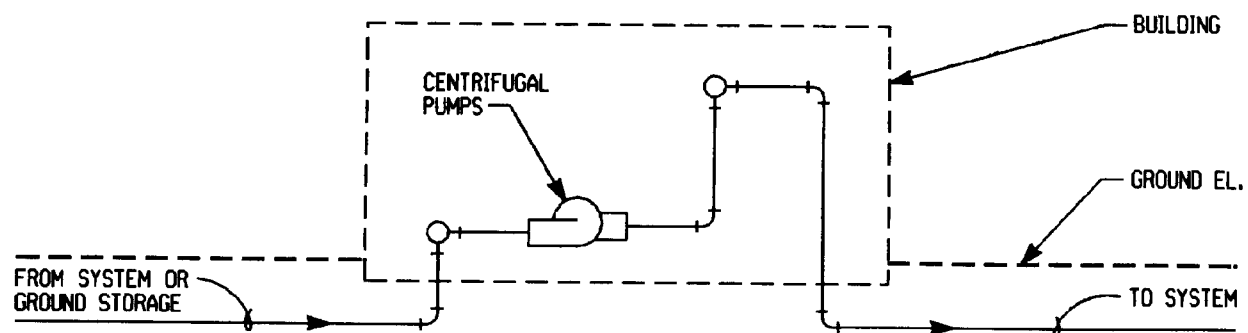
(1) *Booster pumps.* Booster pump may be above-ground or underground. Figure 3-1 illustrates schematic piping of two types. Pump and controls selection for in-line booster pumps will consider minimum suction pressure, and automatic discharge cut-off pressure. For small booster pump applications, as for remote housing or satellite military facilities with peak water demands of less than approximately 1500 gpm the designer should consider a pre-assembled skid mounted package unit including all of its hydrostatic, flow, instrument and electrical components.

(2) *High lift pumps.* Figure 3-2 shows examples of pumps supplying the distribution system.

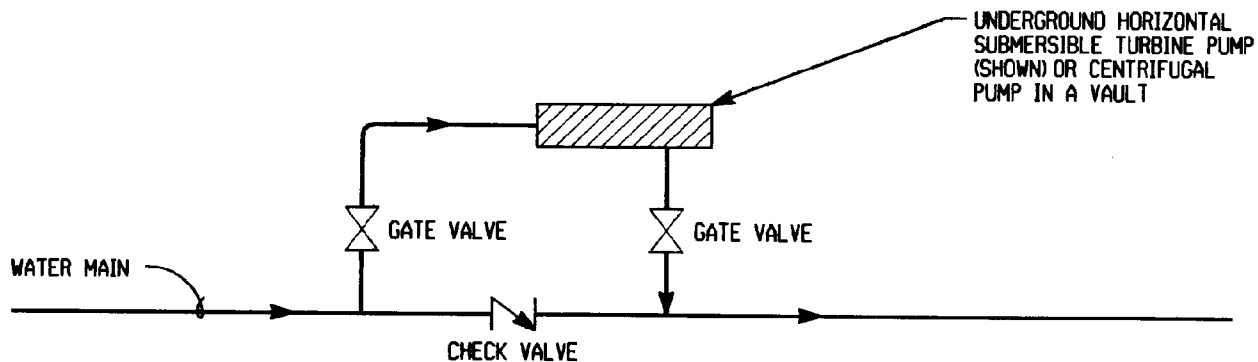
d. Pump curves. With the system head curve defined, it is possible to select a pump to deliver the required capacity. Manufacturer's published pump head-capacity curves for the selected type of pump will be used for this purpose. Since these pump curves usually apply to a particular impeller and pump design, different manufacturers may show slightly different performance for the same type and size of pump. Therefore, several manufacturers' pump curves should be checked to establish a realistic and cost effective criteria for the pump selection. Figure 3-3 shows three types of pump head capacity (performance) curves; a "normal rising" curve, a "drooping" curve and a "steeply rising" curve.

For pumps in a typical water supply and distribution system, only pumps with "normal rising" to "steeply rising" performance curves should be used. Pumps with these characteristics will perform well in parallel operation and will have relatively small capacity change with pressure changes. In addition, the brake-horse power curve will be relatively flat, which will minimize the risk of overloading the motor particularly in applications in direct pressure systems with possible high pressure fluctuations.

3-2. Pump Drives. Pump drives for water supply and distribution pumps will be electric motors. Diesel or other fuels will be considered as a power source only for emergency use. The drivers will be constant speed AC motors of the squirrel-cage-

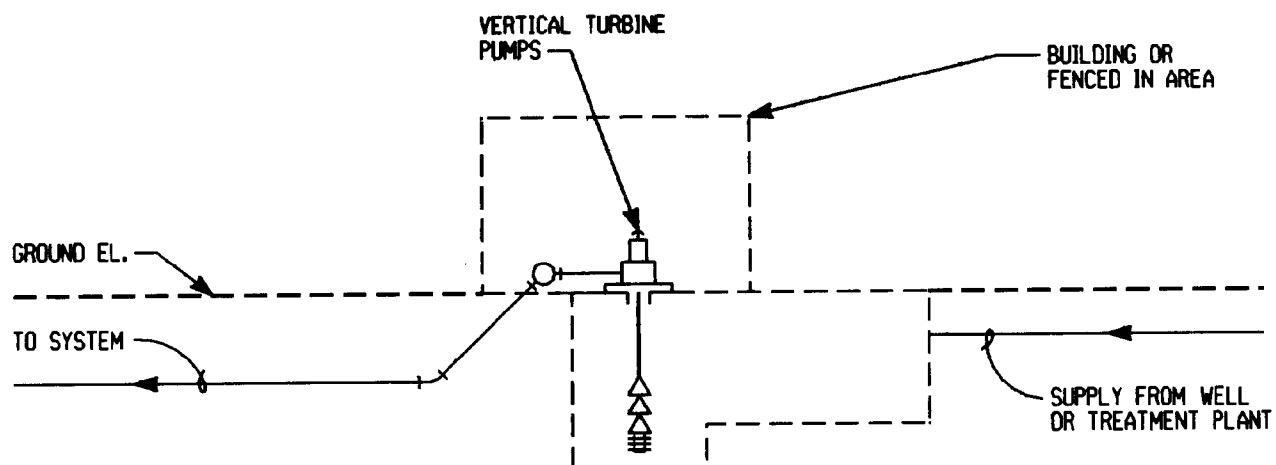


BOOSTER PUMP STATION (SECTION)

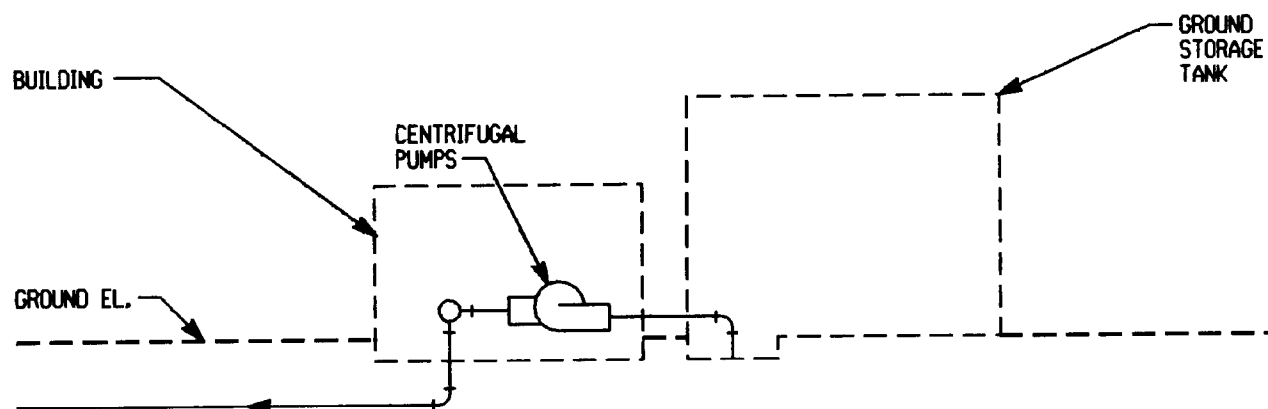


IN-LINE BOOSTER PUMP (PLAN)

Figure 3-1. Booster Pump Stations

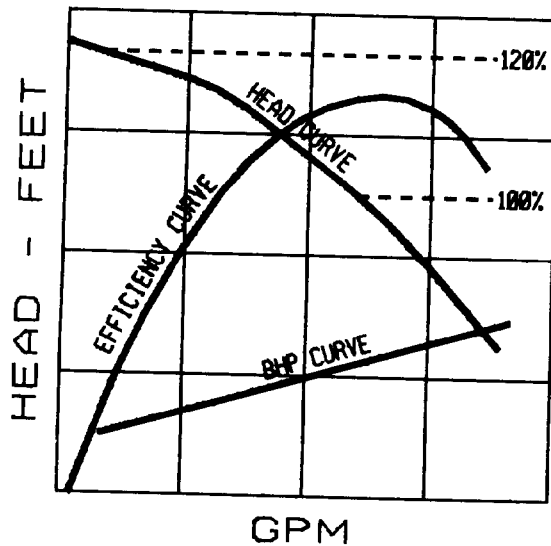


UNDERGROUND RESERVOIR AND PUMP STATION
(SECTION)

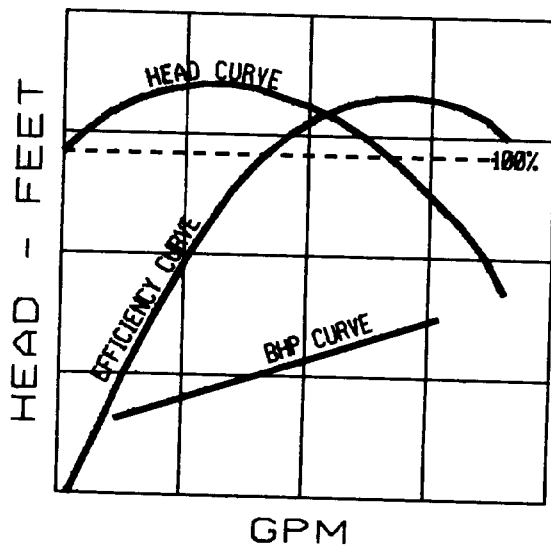


GROUND STORAGE TANK AND PUMP STATION
(SECTION)

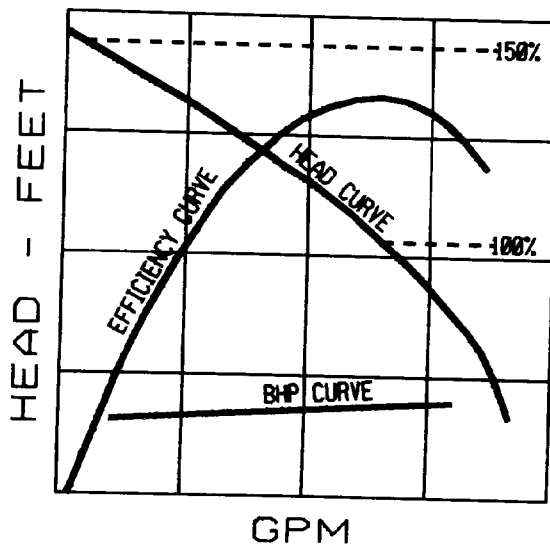
Figure 3-2. Alternative Pump Applications



NORMAL RISING
HEAD - CAPACITY
CURVE



DROOPING
HEAD - CAPACITY
CURVE



STEEPLY RISING
HEAD - CAPACITY
CURVE

Figure 3-3. Pump Curves.

induction, wound rotor or synchronous type. Drives for fire pumps will be in accordance with NFPA 20.

a. Variable speed drives. Variable-speed devices will be considered only for larger pumps and only if justified by an accurate economic analysis. There are many variable speed control systems available. Although the principle may vary, these systems consist of four basic elements: sensor, controller, programmer and variable speed driver. A general recommendation on the type of system for specific pumping applications cannot be made because of differences of available systems. If system requirements, pump capabilities, and overall economics favor consideration of variable speed pump operation, the designer should consult the pump manufacturers and their recommended variable speed representatives to determine the best method of pump control, and to obtain a cost analysis of variable speed versus constant speed for the specific application. Normally the addition of one or more smaller modulating pumps in parallel with the other pumps will be selected to handle any demand for varying pumping rates.

b. Motors. Motors will be selected with sufficient capacity to drive the pumps under service required without exceeding 85 percent of the specified rating. Motors will be in accordance with NEMA MG1. Refer to Hydraulic Institute Standards for discussions on types of electric motors.

3-3. Valving. Valves used in pump station piping system will include: gate valves, globe and angle valves, cone valves, butterfly valves, ball valves, check valves, and relief valves. Globe, ball, cone, and butterfly valves will be best suited as control valves for modulating the flow to provide desired pressure or flow rate. Check valves will not be used in vertical piping.

a. Suction piping valves. A gate valve will be installed in the suction piping so that the pump can be isolated from the line. The stem of this valve may be installed horizontal to avoid air pockets. Butterfly valves will not be installed in pump suction piping.

b. Discharge piping valves. A check valve and a gate or butterfly valve will be installed in the discharge piping with the check valve between the pump and the gate valve. The check valve will protect the pump from excessive back pressure and prevent liquid from running backwards through the pump in case of power failure. The gate valve will be used to isolate the pump and check valve for maintenance purposes. In installations where an automatic surge control valve is needed the check valve will be eliminated provided the drive will not be a wound rotor motor and pump design will

allow some reverse rotation. Pressure relief valves, commonly diaphragm activated globe or angle type, will be installed in discharge piping system for flow control and/or pressure regulation, and to protect pump equipment and piping system from excessive surge pressures which could exceed the ratings of system components.

c. Air release and vacuum relief. Air release and vacuum relief valves will be used on discharge piping for vertical turbine pumps.

d. Control system valving. Pump control systems range from single hand-operated valves to highly advanced, automatic flow control or pump speed control systems. Particularly, in an unattended high head pump station the control valve may have a controller to close automatically when the pump is stopped and to open once the pump has reached specified speed after the pump is started. Control valves are installed to prevent surge pressures, which otherwise cause water hammer and high pressures. A good surge control valve with low head loss will consist of a hydraulically operated valve on the pump discharge complete with speed control device to permit independent timing of both the valve opening and closing speeds. The controller will include hydraulic and safety equipment wired to function in sequence with the pump motor starting gear.

(1) *Hydraulic accumulator system.* A properly selected hydraulic accumulator system can operate on clean water, oil and other fluids. The water system may allow formation of algae, scale and create corrosion in the controls and cylinders and must be constantly checked. Hydraulic oil specially selected for this application provides the best and most trouble free qualities.

(2) *Other control valve systems.* Control valves design and versatility are constantly improving. The selection of a control valve for a specific installation should be made only after consultation with the manufacturers.

3-4. Flow Meters.

a. General. Pump station water is metered for several reasons: to calculate distribution system losses by subtracting the total of meter readings from total supply, to monitoring pump efficiency, and to determine gross billings for water supplied. High rate of accuracy and wide range criteria will be desirable in most pump station flow meter applications. Because of constant improvements in old technologies and because new technological developments continuously provide the market with new products, the designer must review the state of the art before making final meter selection.

b. Design criteria.

- (1) *Accuracy.* + 1% of rate
- (2) *Rangeability.* To cover complete design range
- (3) *Maintainability.* Routine by user. Major overhaul by readily available factory service
- (4) *Initial cost.* Minimal
- (5) *Operating cost.* Minimal
- (6) *Design life.* 20 years minimum

c. *Meter selection.* The two most common flow meters in water pumping installations identified in the order that they best comply with the design criteria are as follows:

(1) *Ultrasonic meter.* Ultrasonic meter for clean liquids using "transit time" technology will meet all the set criteria. Straight approach length equivalent to 10 pipe diameters is important. No maintenance is required.

(2) *Current meters.* Current type meters used for pump station discharge and mainline measurements include turbine and propeller meters. Accuracy of these meters are +2% instead of +1% over an approximate rangeability of 10:1. These meters require a length equivalent to 5 pipe diameters straight approach and periodic maintenance. Turbine meter standards for sizes 1 1/2 inch through 12 inches are covered in AWWA C 701 and propeller meter standards for sizes 2 inches to 36 inches in AWWA C 704.

(3) *Selection features.* Additional advantages of the ultrasonic meter include non-contact with liquid, versatile design regarding data monitoring and clamp-on transducer for any size pipe over 1 inch in diameter. The meter is most cost effective for larger pipe applications. This type of meter does not require any pipe by-pass arrangement with shut-off valves. The advantages of current meters are lower initial cost for small size meters, simplicity in design, and historically a proven product over many years.

(4) *Flow recorders.* Flow recorders may supplement the flow meter device to record pump performance, condition of pump, and energy usages rates. For complex installations, flow recorders may be part of a remotely located controller or part of remote stations which monitor other data such as speed indication, vibration monitoring, and bearing or casing temperature indicators. Flow recorders will be used to indicate flow fluctuations over the course of a day. Technological advances have made transducer output measurement possible with self-balancing recorders and computer-compatible data-gathering systems. Limits on accuracy, distance of signal transmission, and speed of response will determine data transmission methods. Mechanical signals from a metering device can be converted to electrical form and vice versa, but may be limited by

active physical links and inertial effects. Transmission of data from a transducer to a recording system may be accomplished by a pair of wires. Radio telemetry techniques may be useful where attaching wires are impractical. Readouts may be in analog form in strip and dial chart recorders, and analog signals on tape. In digital recording, conversion of signals to numerical values may be by electromechanical or one of a variety of electronic systems. The latest state-of-the-art techniques will be reviewed with measurement and instrument manufacturers when selecting recording and transmission equipment.

3-5. Piping Layouts.

a. *Suction piping.* Proper design of suction piping is important to minimize pressure losses and allow sufficient flow into the pump. Many net positive suction head (NPSH) problems will be eliminated by proper suction piping design. Suction piping must be kept free of air leaks. Pipe joints will be screwed or flanged joints for smaller sizes and flanged for larger sizes.

(1) *Suction pipe sizing.* Suction piping should be as short as possible but never smaller than pump suction opening. If a longer suction pipe is required, it should be one or two sizes larger than the pump suction opening depending on the length. Suction piping of same size as pump suction nozzle for a double suction pump will have a minimum of 10 pipe diameters straight run from the suction flange of the pump. The pump manufacturer of the selected pump will be consulted regarding special piping arrangement for vertically mounted pumps or for other space limitations. Suction pipe headers in multiple pump installations will have headers sized so that each pump receives its proportional flow amount.

(2) *Suction elbows.* To avoid high unequalized thrust loads that will overheat bearings and cause undue wear as well as affecting hydraulic performance, suction elbows for double suction pumps will be positioned in a vertical position only to allow the liquid to enter evenly on both sides of the impeller. Long radius elbows will be used.

(3) *Pipe slope.* Suction pipe will slope upward to the pump connection when operating on suction lift. When reducing the piping to the suction opening of the pump and where operating on suction lift, an eccentric reducer with the eccentric side down will be used to avoid air pockets.

b. *Discharge piping.* If the discharge pipe is short, the diameter of the pipe will be same as pump discharge nozzle. If the discharge pipe is long, the diameter will be increased by one or two sizes depending on length.

c. Meter runs. At meter locations the required straight approach and downstream length of straight pipe must be considered. It is good practice to allow straight runs of 10 and 5 pipe diameters for upstream (approach) and downstream of meters in the piping layout. This will accommodate any type of meter.

3-6. Controls.

a. *Description.* Pump controls will have the capability to provide the desired flow rates, pressures and liquid levels; to provide protection from pump and piping system damage; and to serve as a tool to find system problems which may need operational adjustment, repair or maintenance. Control systems consist of the following:

- (1) Sensing and measuring elements (primary device).
- (2) Comparison and relaying element (controller).
- (3) Final control element (as a valve) to produce the required change including an actuator to move the control element.

b. *Pump control systems are divided into on-off and modular.* The successful operation of the control system depends on several factors as follows:

- (1) An accurate definition of the control job to be done.
- (2) A review and evaluation of available devices/systems suited to do this specific job.
- (3) Selection of device and system design in cooperation with the manufacturer of the selected equipment.

c. *Sensing and measuring elements.* Automatic pump control and valve operation sensing and measuring elements will detect values of changes in liquid level pressure or flow rate and emit a signal which may be amplified and/or converted into another medium in a transducer as rotary motion or air pressure to electric voltage. The most common primary devices used in waterworks are liquid level sensors, pressure sensors and flow meters.

d. *Comparison and relaying element.* The variable that is most convenient or advantageous to measure is rarely the one best suited for direct use in the control system or for actuation of the final control element. Conversion of sensed or measured variable values into another signal medium is therefore necessary. The comparison and relaying means, the transducers and transmitters, are usually housed together in the controller which often is physically separated from the primary device.

e. *Final control element.* For the final control element, valves and pumps serve for on-off control and modulating needs in water pumping systems. A

control valve is a valve that modulates the flow through it to provide the desired downstream or upstream pressure or flow rate. Although almost all valves can be partly closed and control flow to some degree, the term "control valve" means a specialized type of power-activated valve designed to modulate flow to meet system demands or for surge protection. The term "pump" as a final control element is a pump provided with automatic variable speed control drive to maintain an essentially fixed flow rate and for controlled flow rate increase/decrease at start/stop of pump to minimize surges in the system. Because of unique features available from control equipment manufacturers, the designer should contact the manufacturers before selecting valve and pump control equipment.

f. *Instrumentation.* Instrumentation for a water pumping station will supervise and monitor the routine operation of pumps, their drives and accessories to sustain a desired level of performance and reliability. Alarm situations will be identified, such as low delivery flow and low pressure, pump failure, power failure, and low suction head (water loss). Alarm situations will include engine drives as required to support the system reliability factors. The type and extent of supervisory instrumentation for the installation will be determined from:

- (1) Pump application in terms of what effect the pump will have on the system if it failed to perform its function.
- (2) Pump design, type, size and parameters that could affect reliability and hydraulic performance such as variable speed pumps and long shaft high speed pumps, which may need monitoring of vibration, bearing and hydraulic performance.
- (3) Operator experience with similar pumps may indicate a need for applying supervisory instrumentation.
- (4) Installations with operators in attendance will need minimum monitoring while unattended pump stations in remote location will require substantial monitoring of measurements and alarms.

3-7. Reliability Factors.

a. *General.* A pumping station usually represents one of the major and most costly components of a water distribution system, therefore pump station reliability will be considered. The number of pumps will depend upon present and future needs. An economic analysis should be performed to determine the number of pumps to be installed. In smaller stations a single pump may be most economical to meet the peak demand. Whenever a single pump is sufficient, two equal size pumps,

each able to handle the peak demand, must be provided and set-up to alternate. Whenever two or more pumps are cost-effective to meet the peak demand, additional pump capacity or pumps must be installed so that peak demand can be met with the largest pump out of service. All pumps should alternate. Raw water pumping stations must have a minimum of three pumps. To prevent large pumps from repeatedly cycling on and off during periods of low demand, one small modulating pump, commonly known as a jockey pump, shall be installed.

b. Emergency power. During curtailed power or brown-out, emergency power is usually provided by a diesel generator although other standby fuels such as gasoline and natural gas may be used if available and economical. Diesel engines and diesel engine fueling systems are preferred as more reliable. Emergency power will not be provided for standby equipment. Emergency power will be limited to average demand conditions for water distribution and transmission systems and to 50 percent of the treatment plant's capacity for raw water supply stations.

c. Factors. The reliability of the pumping station as a whole and of its individual components must be determined. Some typical factors and components which may be included in a reliability

and availability evaluation are listed as follows —

- (1) water demand and emergency storage
- (2) preventative maintenance
- (3) wear/life expectancy of subcomponent
- (4) repair
- (5) power transmission
- (6) parallel operation and stand-by equipment
- (7) emergency power
- (8) surge protection
- (9) pumps
- (10) valves
- (11) piping
- (12) motors
- (13) controls
- (14) time factors

Reliability evaluation should be part of the planning and design process to make certain that a reliable and cost effective design alternative will be implemented. Two independent power supplies might be considered for the most critical main pumping stations. Existing power supplies will be investigated to determine historically the number of power outages and length of outages occurring over a pumping period. Where direct connection of an engine drive to a pump is considered, a cost analysis will be made comparing engine generated electric power versus direct engine connection.